# Thin Edgeless Silicon Pixel Sensors on Epitaxial Wafers after Irradiation

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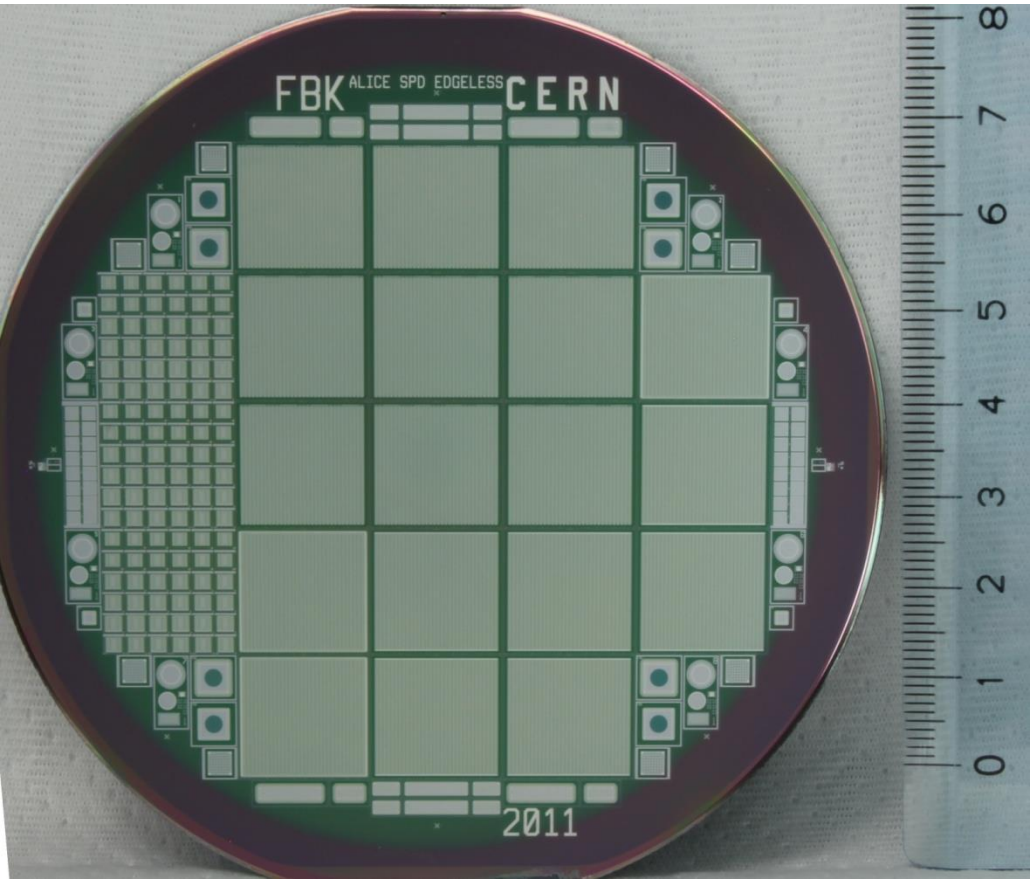
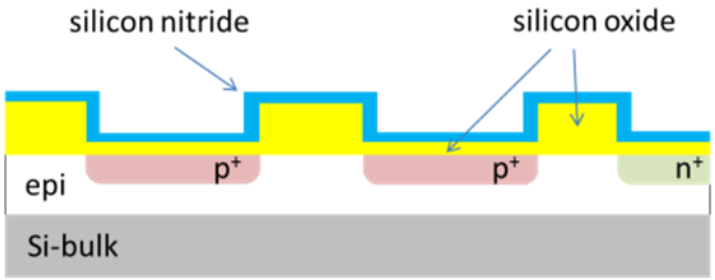
# Edgeless Pixel Sensors on EPI Wafers




- $P^+$-on-$N$ pixel sensors
- ~100 µm thick HR-EPI layer
- thick heavily doped substrate (to be removed in the final sensor)
- Sensor design compatible with ALICE pixel readout chips
- “Active Edge” technology with DRIE-etched trenches
- Similar sensors but without active edges already made and successfully tested on beam

# Edgeless Sensor Fabrication

a)




STD process

b)


Trench etching by DRIE :

~ 5 µm wide, ≥ 50 µm deeper than EPI

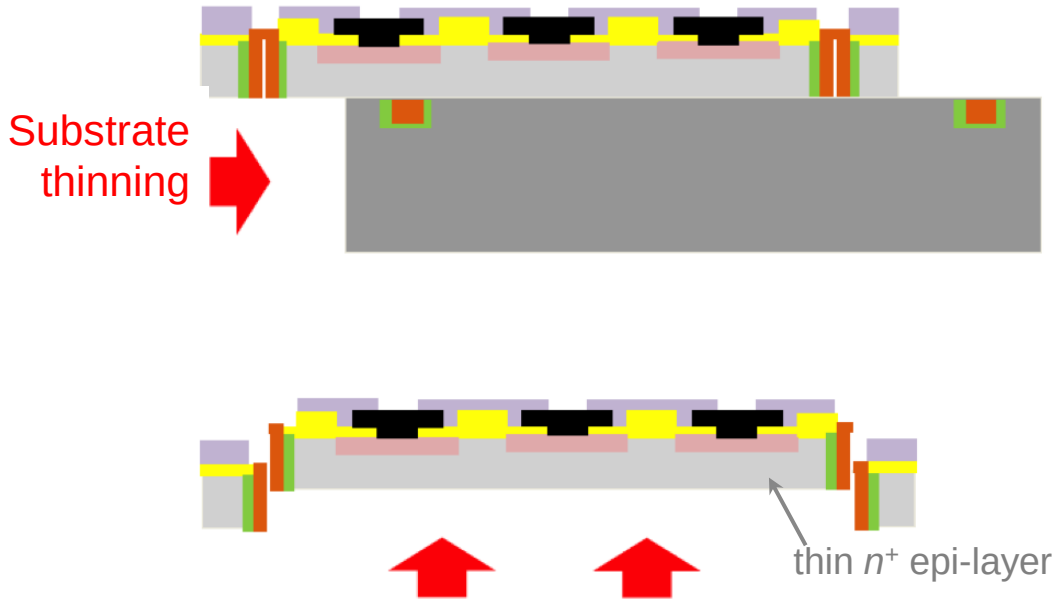
→ Trench doping

→ Trench filling with polysilicon

c)


STD process

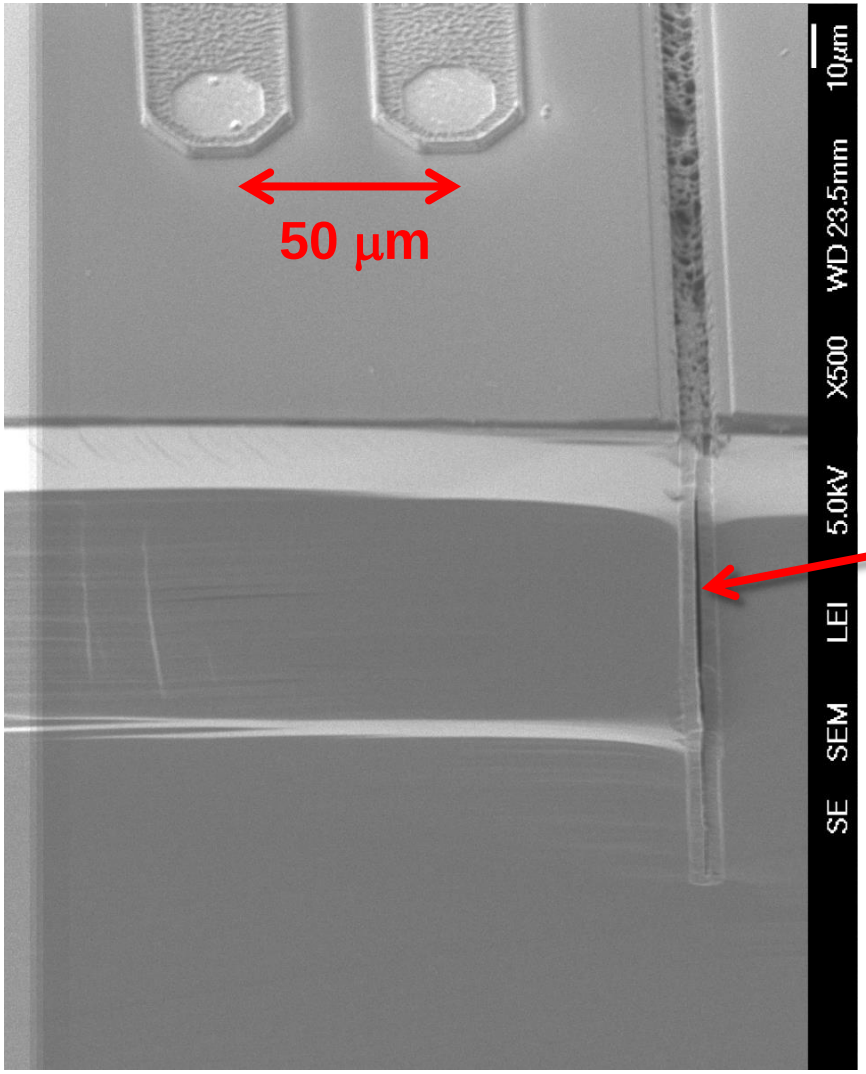
# Edgeless Sensor Fabrication




Device separation along the trenches

- A thin layer of heavily doped substrate is left, acting as an ohmic backside contact.
- If required for the bias contact, the device can finally be metallized on backside.

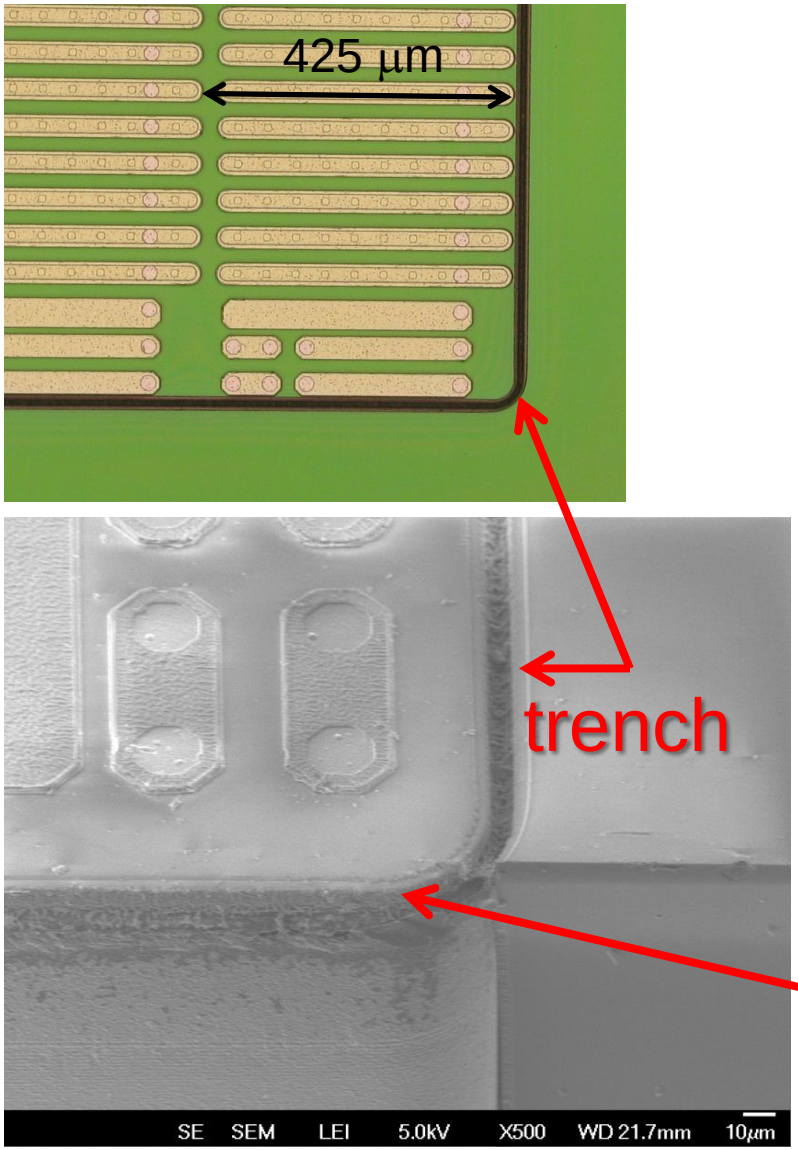
# Details of the Trench




During polysilicon deposition, the trench gets filled and sealed close to the surface, leaving a narrow unfilled gap deeper into the bulk.

This allows separating the devices along the trench after the substrate is thinned.

# Trench on Edgeless Pixel Sensors

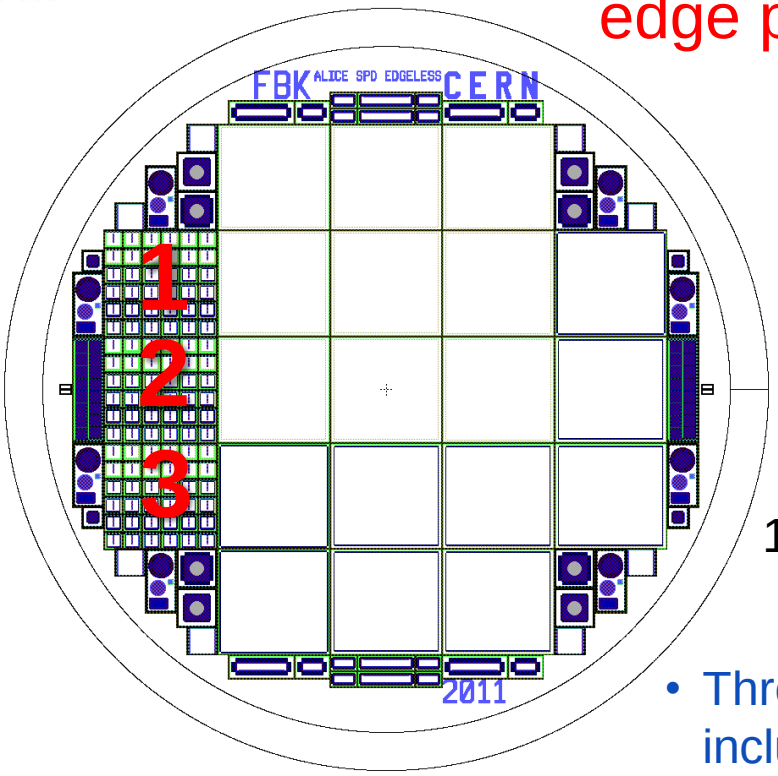


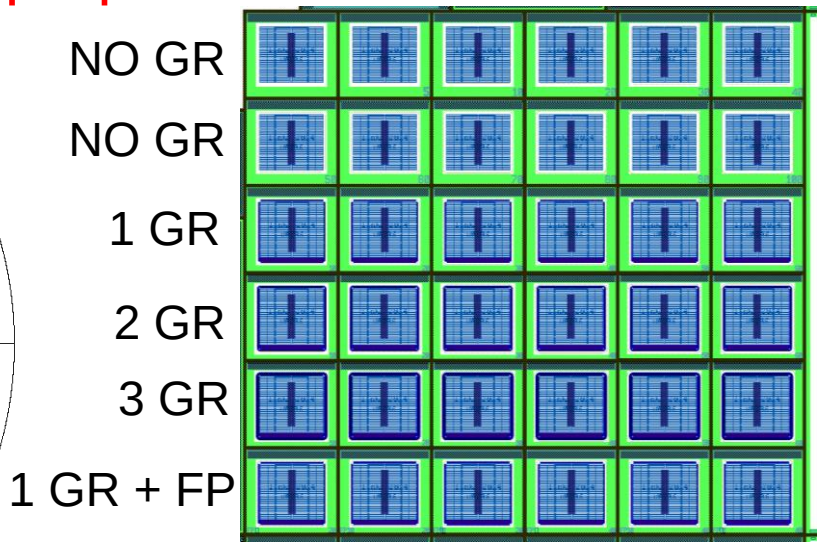

The sensors are surrounded by a trench, located at varying distances from the outermost junction.

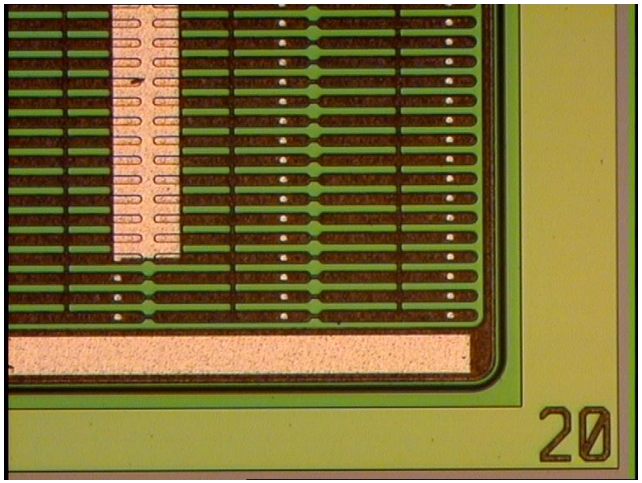
Some sensors have guard rings surrounding the pixels.

Edge of chip separated along the trench

# Structures for testing breakdown and edge properties




- Three identical Groups (#1, 2, 3) each of them including 6x6 pixel structures
- 6x6 design variants, differing by:
  - number of Guard Rings (0, 1, 2)
  - distance last-implant to trench (5 - 100 µm)
- On each structure, an array of 30 × 4 pixels, shorted together by metal lines, to facilitate testing

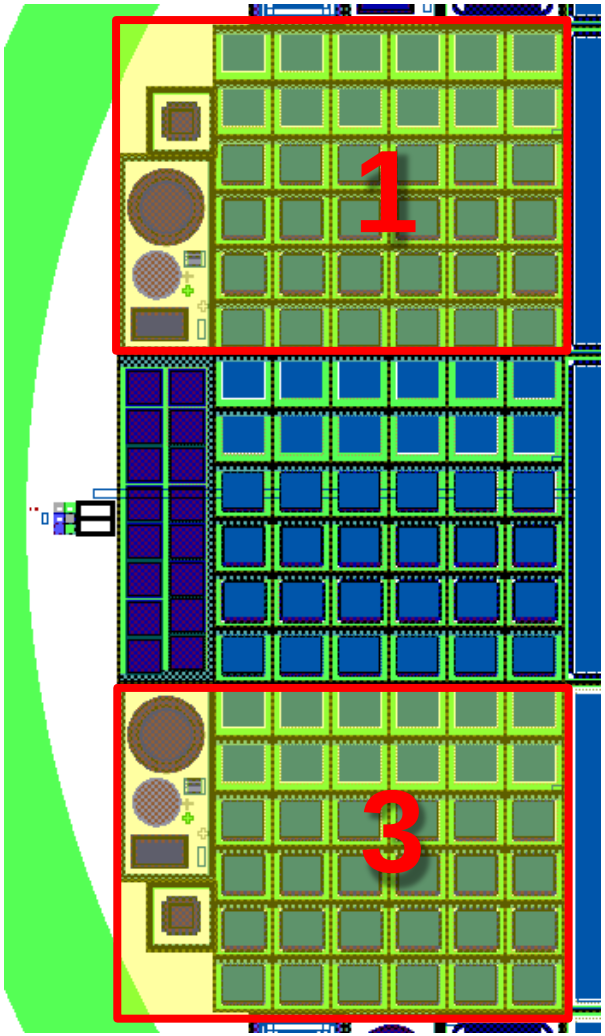
# Irradiation at JSI (Ljubljana)

Selected devices from three wafers were irradiated with reactor neutrons in Ljubljana, at three different fluences (1-MeV $n_{eq}$):

- $\Phi_1$: 1.0E14 $cm^{-2}$
- $\Phi_2$: 5.0E14 $cm^{-2}$
- $\Phi_3$: 2.5E15 $cm^{-2}$

At each fluence, irradiation of:

- one pair of pixel test structures (Groups # 1, 3) with the adjacent standard test pattern
- a strip of square diodes reproducing the various Trench-GR options.



# From Test Structures

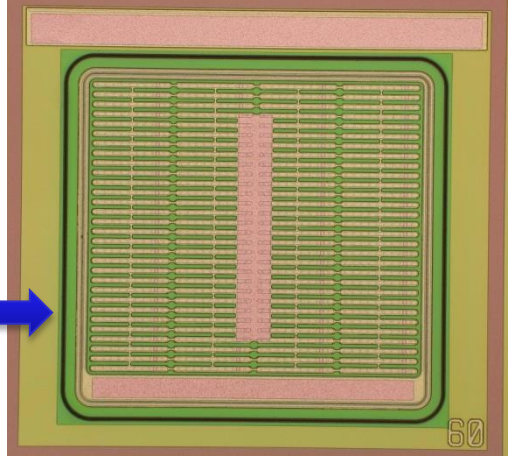
Type inversion at 1e14 1MeV $n_{eq}/cm^2$

| Fluence (1MeV $n_{eq}/cm^2$) | V depletion (V) | $N_{eff}$ ($1x10^{12}$ $cm^{-3}$) | Leakage @ 100 V ($\mu A/cm^2$@ RT) |
|---|---|---|---|
| 0 | 15 | ~ 1 | ~ 5 $nA/cm^2$ |
| 1e14 | 8 | 1.0 | 60 |
| 5e14 | 25 | 3.1 | 210 |
| 2.5e15 | 100 | 12 | 990 |

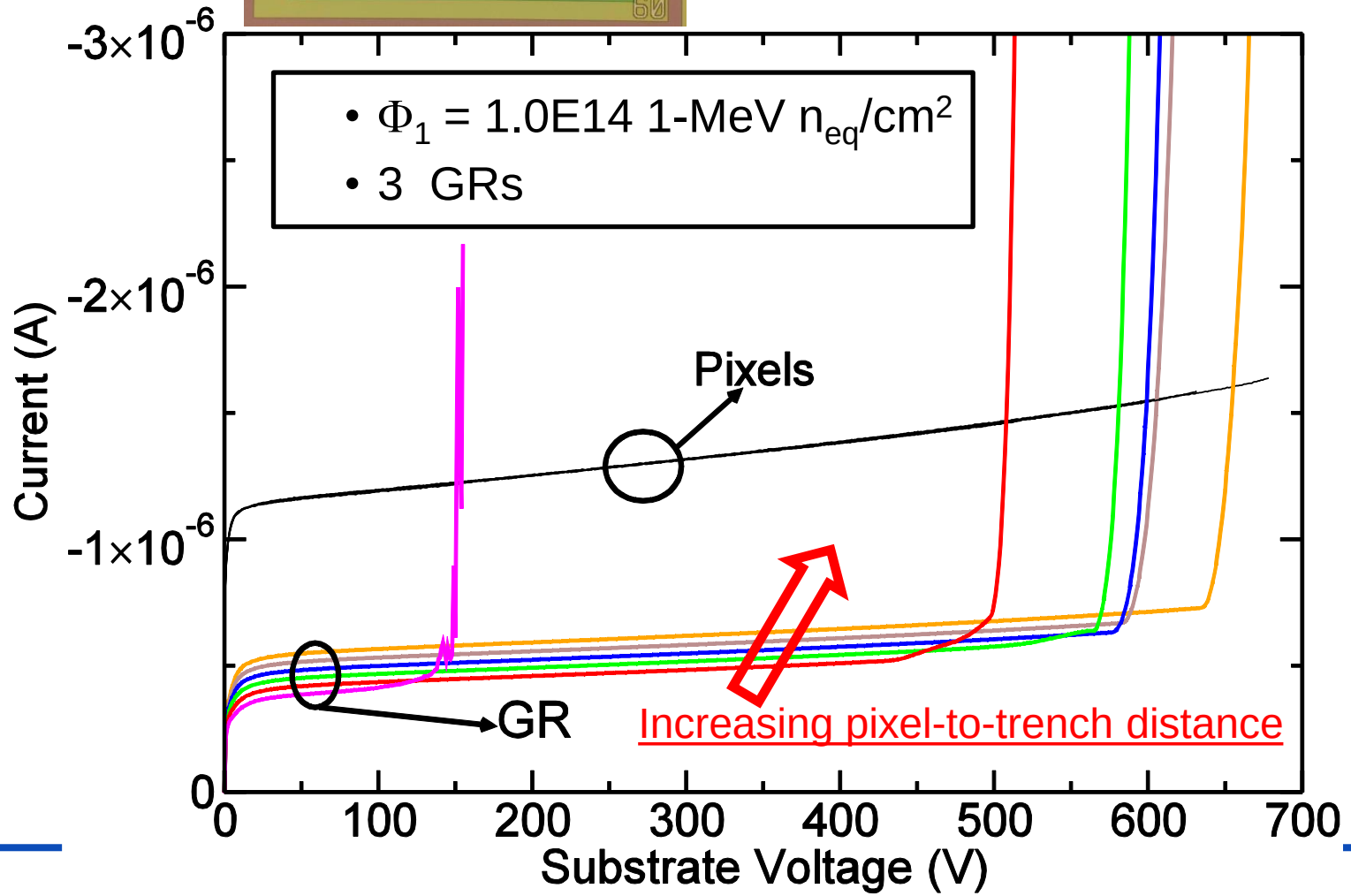
$$\frac{\Delta I}{V} = \alpha\Phi \qquad , \alpha = 4.0e\text{-}17\ A/cm$$

# Example of I-HV

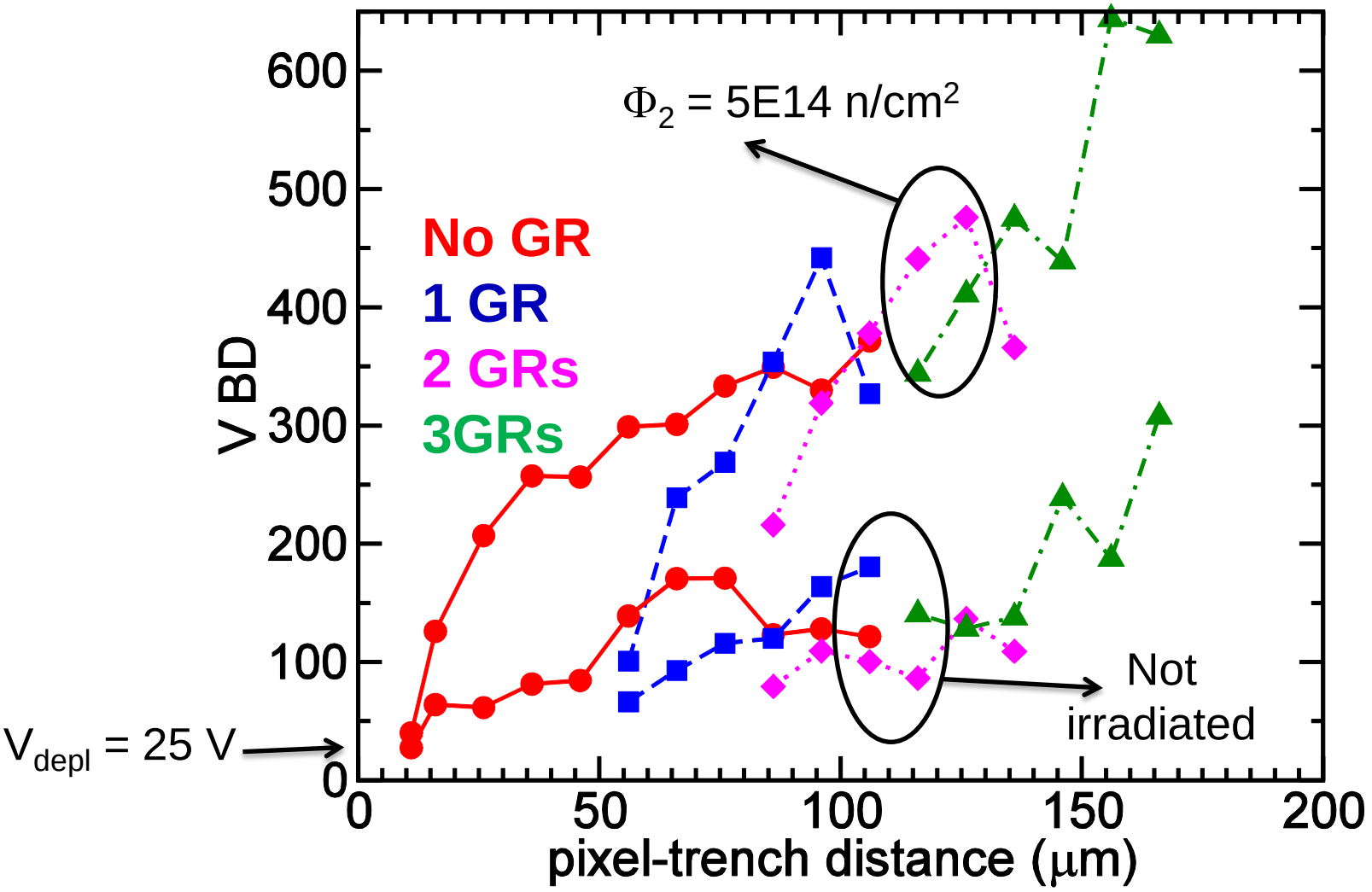
Pixel pitch:
425 μm x 50 μm



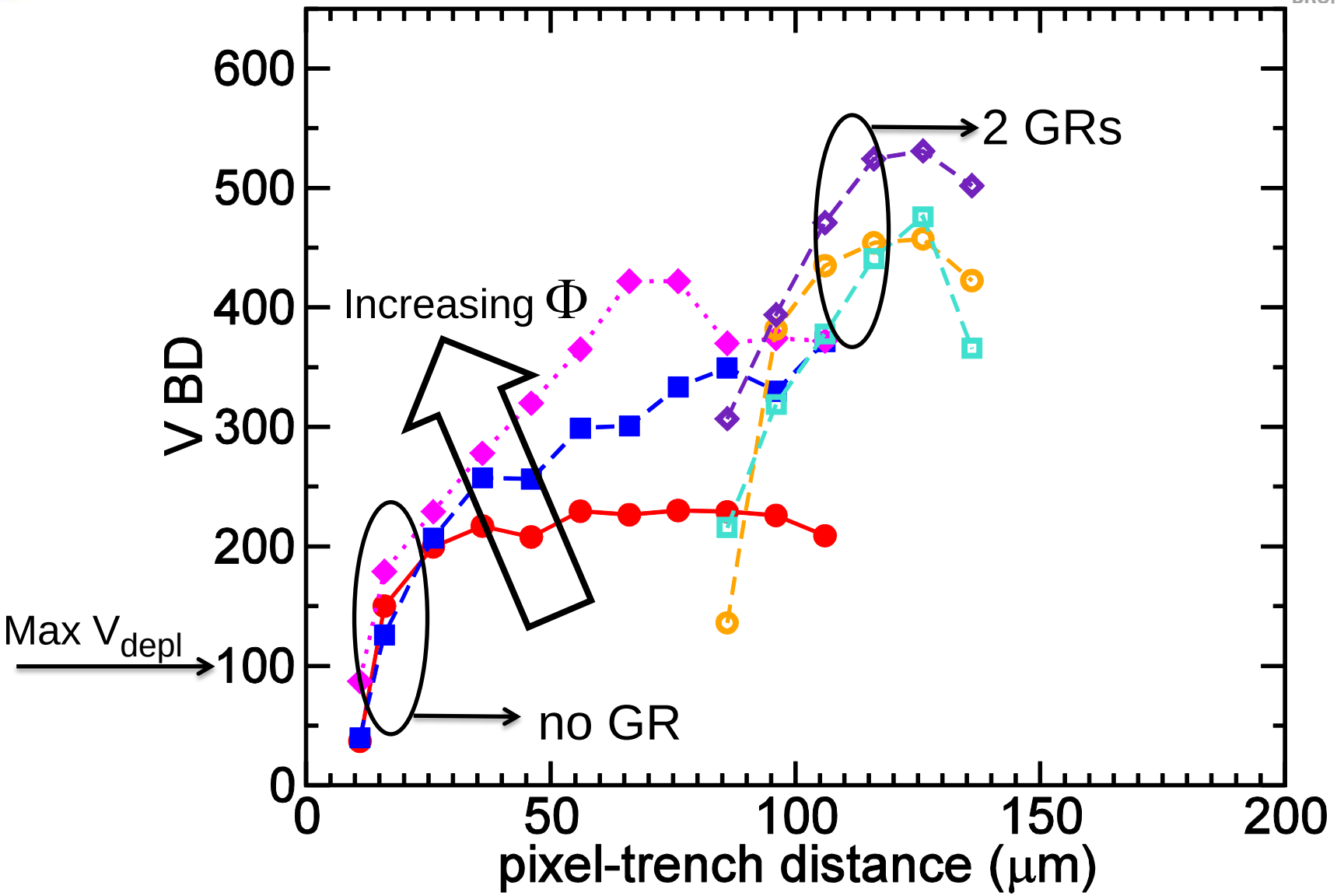
- Pixel current ~ $\alpha\Phi$
- Sharp breakdown on GR



# $V_{BD}$ vs #GR vs Distance



# $V_{BD}$ vs #GR vs Distance vs $\Phi$



# Conclusions

- A viable process has been set up for fabricating
  thin “edgeless” sensors,
  minimizing the amount of passive material.
- Static characterization (before and after irradiation) is OK.
- Breakdown voltage is more than adequate.
- Narrow-edge versions (40 – 50 μm) with no GR seem the most interesting.

- ALICE is looking at monolithic pixels, so R&D stops here.